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DeepWind
an innovative wind turbine concept for offshore

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Risø DTU[1], DTU MEK[2],UNI TRENTO[3], NENUPHAR[4], VESTAS[5],MARINTEK[6],DHI[7],MARIN[8],TUDelft[9]

Abstract

This poster describes the progress in developing a new offshore floating wind turbine called *DeepWind* which has been granted by the EC under the FP7 programme platform *Future Emerging Technology.* The project is coordinated by Risø DTU and the consortium is represented by 9 research and 3 industrial partners, with experience and competences in different technological areas, in particular offshore technology. The 4-year duration project started Oct. 2010. 4 PhD positions are associated with the project.

Introduction

The project idea was emerging from the necessity of technological improvement in offshore wind energy playing a steadily increasing role calls for dedicated technology rather than being based on existing onshore technology transported to sea environment. DeepWind is directing towards offshore wind energy where cost is approximately the same as for onshore MW wind turbines.

The DeepWind concept has been described previously on concept technology, challenges and components in [1,2,3]. In order to be able in detail to evaluate the technologies behind the concept, DeepWind comprises:

1) numerical tools for prediction of energy production, dynamics, loads and fatigue, 2) tools for design and production of blades 3) tools for design of generator and controls, 4) design of mooring and torque absorption systems, and 5) knowledge of friction torque and lift and drag on rotating tube. The technologies need verification, and in the project verification is made by: 6) proof-of principle by testing of a small, kW sized technology demonstrator, partly under real controlled laboratory conditions, 7) integration of all technologies in demonstration of the possibility of building a 5MW wind turbine based on the concept, and an evaluation of the perspectives for the concept.

The DeepWind concept differs from traditional spar-type concepts known from offshore oil and gas installations due to the rotation of the structure. A very large torque has to be absorbed by the mooring lines at the bottom of the structure. This can be achieved by using rigid arms to connect the tower to the mooring lines and applying sufficient horizontal component of the pre-tension in the lines in order to absorb this torque.

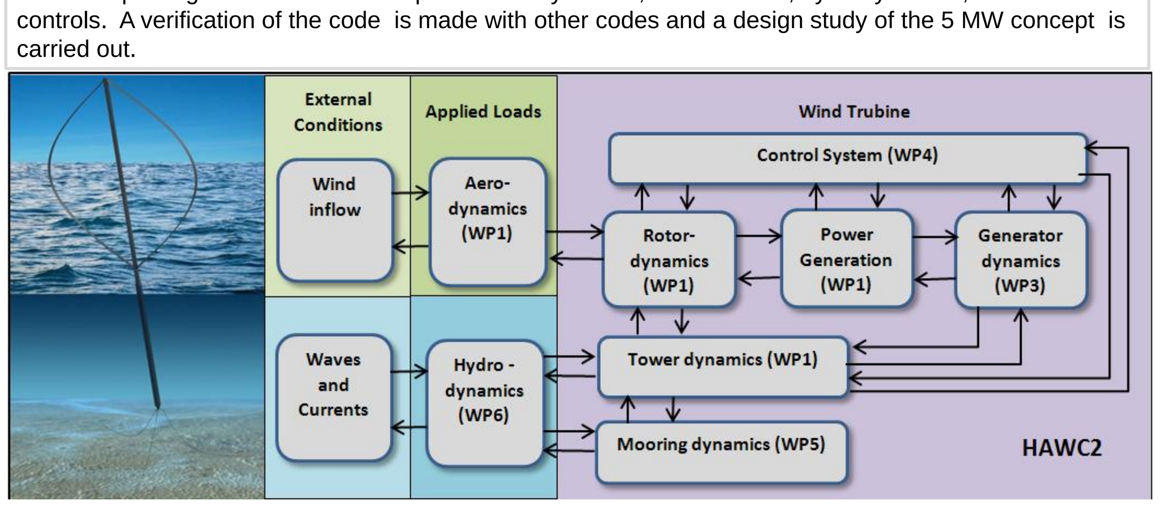
A recently developed optimization tool, WINDOPT [4,5], will be used to select a cost optimized mooring system and spar type floating support structure. This tool utilizes efficient design tools for analysis of mooring system forces and vessel motions, and combines this with a gradient method for solution of non-linear optimization problems with arbitrary constraints.

Objectives

This paper informs on the progress developments and plans conducted up to now in WP 1, 2, 5, 6 and 7. The work package contents are describes briefly:

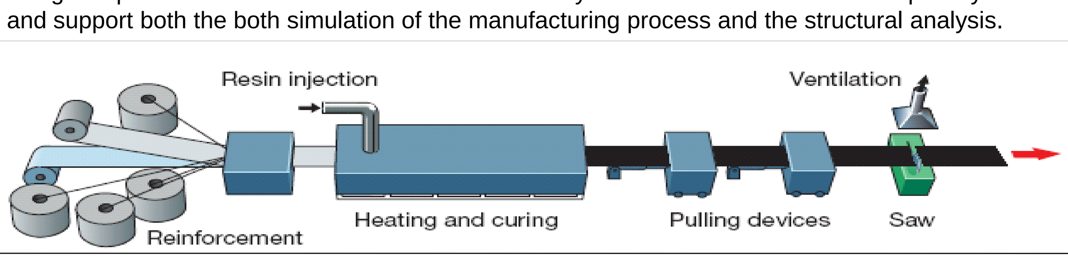
WP1- A NUMERICAL SIMULATION TOOL

The work package tool embrace DeepWind aerodynamics, aero-elastics, hydrodynamics, loads and controls. A verification of the code is made with other codes and a design study of the 5 MW concept is carried out.



WP2- BLADE MANUFACTURE PROCESSING TOOL

The work package defines the ideal blade based on knowledge on geometry, loads, materials and processing technology. This is achieved by developing a numerical model which encounters the pultrusion manufacturing process in such a detail that both the structural design and production parameters of a pultruded blade for the Darrieus turbine can be optimized. A model rotor (~2 m diameter) will be manufactured for wind tunnel tests in the new Open Jet facility of TU Delft to validate the optimized design. A profile will be manufactured and structurally tested to demonstrate the capability of the design and support both the both simulation of the manufacturing process and the structural analysis.



WP5 -MOORING, FLOATING AND TORQUE ABSORPTION SYSTEM

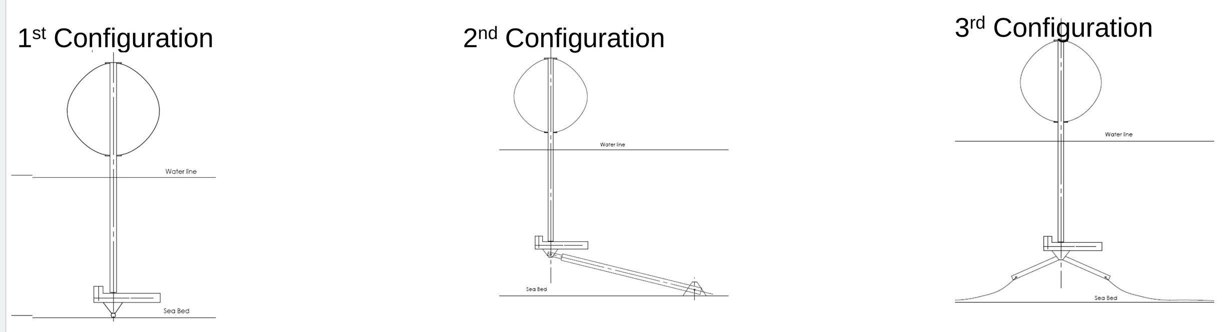
The work package identify feasible floating support structures, cost-optimised anchoring system and power take–off cable configuration for a vertical axis floating wind turbine

WP6 -EXPLORATION OF TORQUE, LIFT AND DRAG ON A ROTATING TUBE

Exploration of torque(friction), lift and drag forces on a rotating circular cylinder in water employing composite modeling, an integrated and balanced use of physical and numerical models. The influence of waves and currents are investigated and analyzed for combined effects. Results from the physical model experiments and refined numerical modeling will be parameterized to construct an engineering model, which will be implemented into the aero-elastic code, WP1.

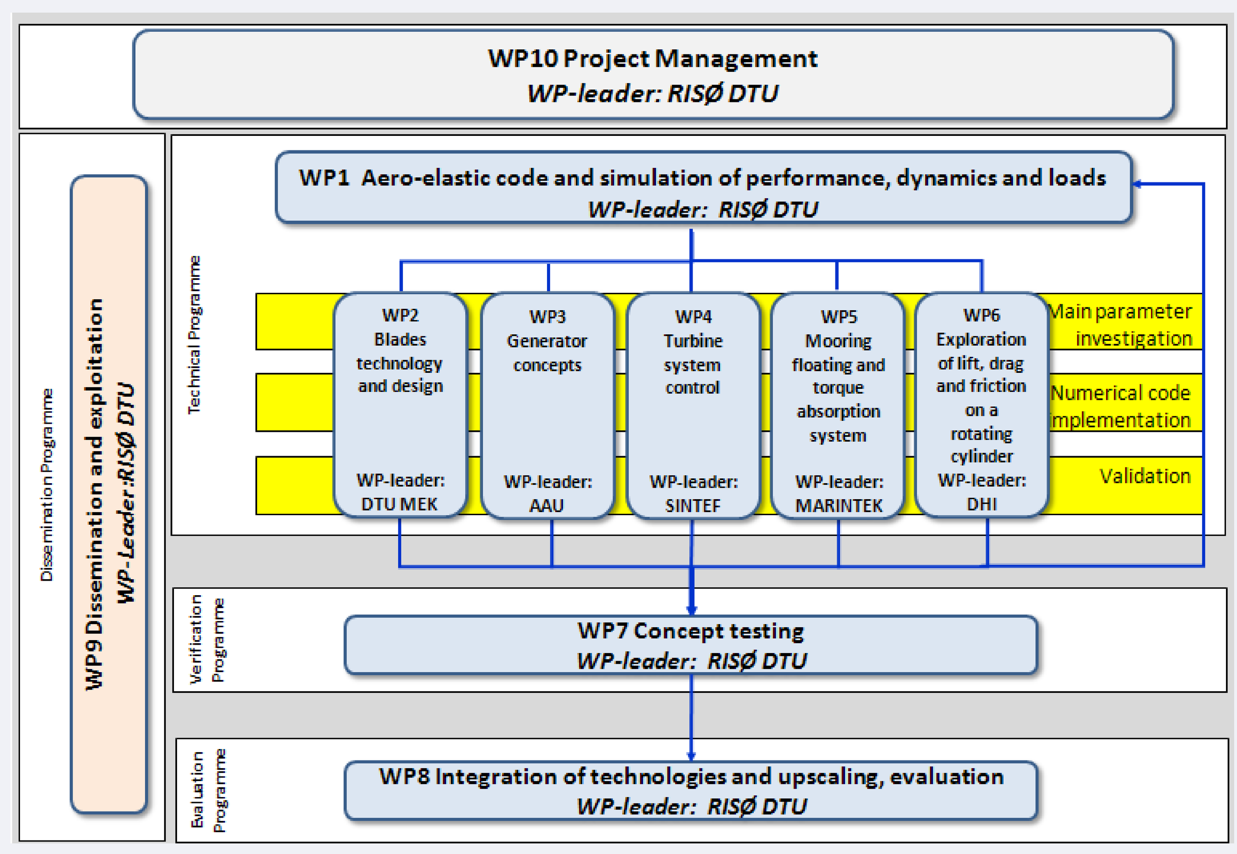
WP7- Proof-of-principle experiments

The work package designs a wind turbine of about 1kW, from input by WP 1 and WP 3 design tools. VESTAS provides the mechanical structure and mooring; NENUPHAR the blades and Aalborg University the generator and controls. The turbine is put in Roskilde fjord right next to Risø Campus for demonstration of dynamic behaviour with important movements (DOF's) under different operating conditions in regular field conditions. These tests will demonstrate basic behaviour and control.



A dedicated test program in controlled laboratory environment (oceanic lab at MARIN, wind tunnel tests at Trento, and TUDelft is worked out in the course of modelling the concept, in order to explore and understand the modular pieces of the concept.

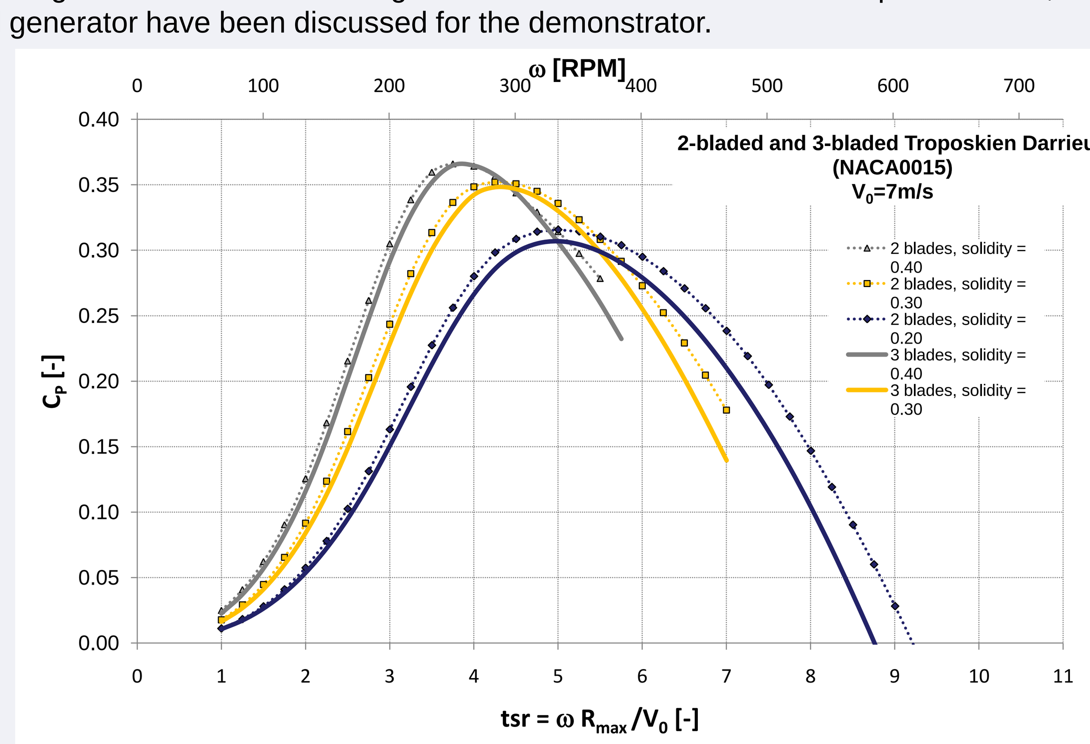
S/T Methododology

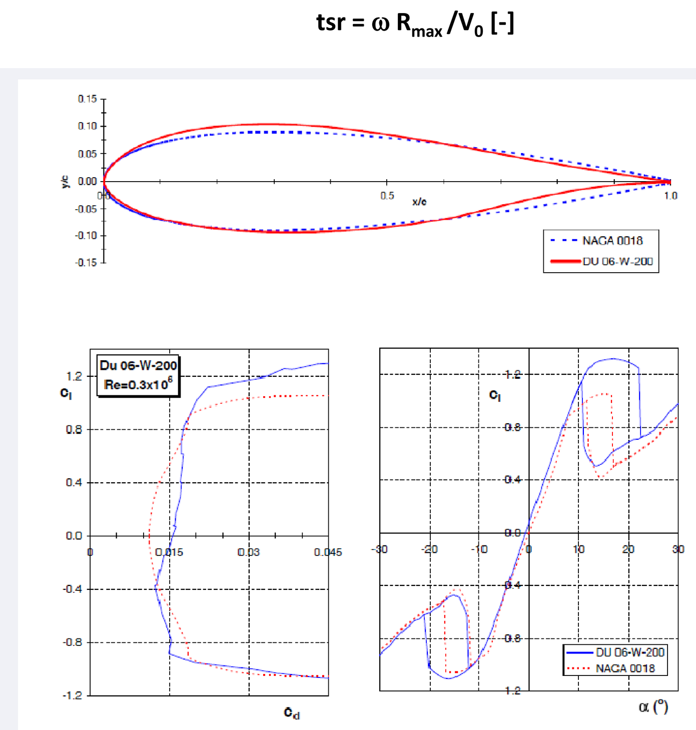


The project has been divided in nine work packages; six of them reflect the technological challenges within this new field of technology, one the validation of the results, one the integration of the technologies in a 5MW and 20MW design; one on the dissemination of the results.
1. Aero-elastic code and simulation of performance, dynamics and loads
2. Blade technology and blade design
3. Generator concepts
4. Turbine system controls
5. Mooring, floating and torque absorption systems
6. Exploration of torque, lift and drag on a rotating tube
7. Proof-of-principle experiments
8. Integration of technologies and up-scaling
9. Dissemination and Exploitation
In order to combine the results from the different technologies another dedicated work package will deal with project management. An advisory board (L.O.R.C., DNV, Grontmij CarlBro, Sønderjylland Maskinfabrik, Vatenfall, Vertax Wind LtD) will ensure the connection of the project with the actual needs of the offshore industry.

Results

In WP1 a parametric study of solidity and airfoil type on rotor performance has been carried out. The selection of symmetrical(NACA00-) and non-symmetrical (DU 06 W) airfoil against criteria for selecting a 2- or 3-bladed rotor in terms of performance, loads and generator have been discussed for the demonstrator.

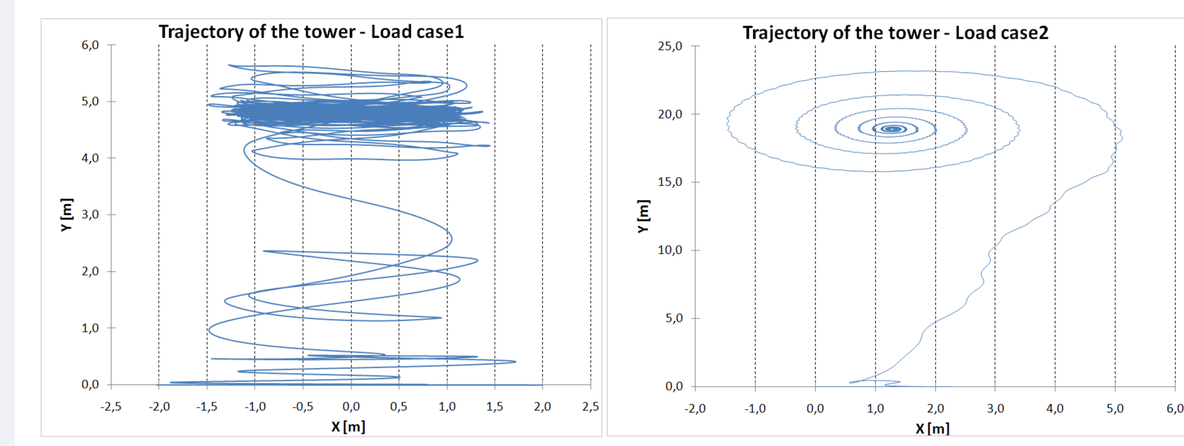


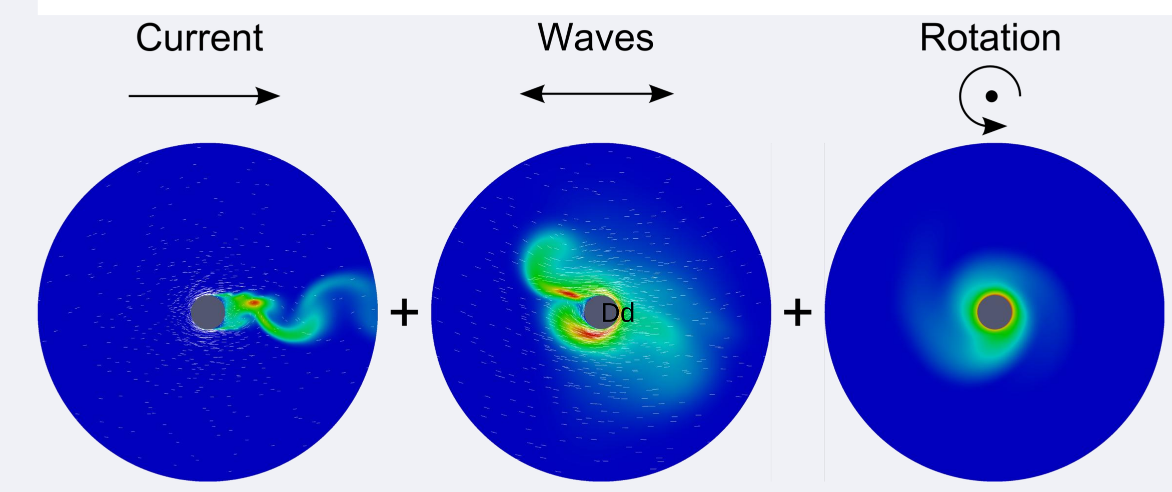


The 2, 5 and 20 MW concept has been simulated for loads with HAWC2[. In terms of dynamic effects due to fluid interaction on the rotating spar simulations with ELIPSYS have shown for a 5 MW turbine a contribution from friction of about 2%[3].

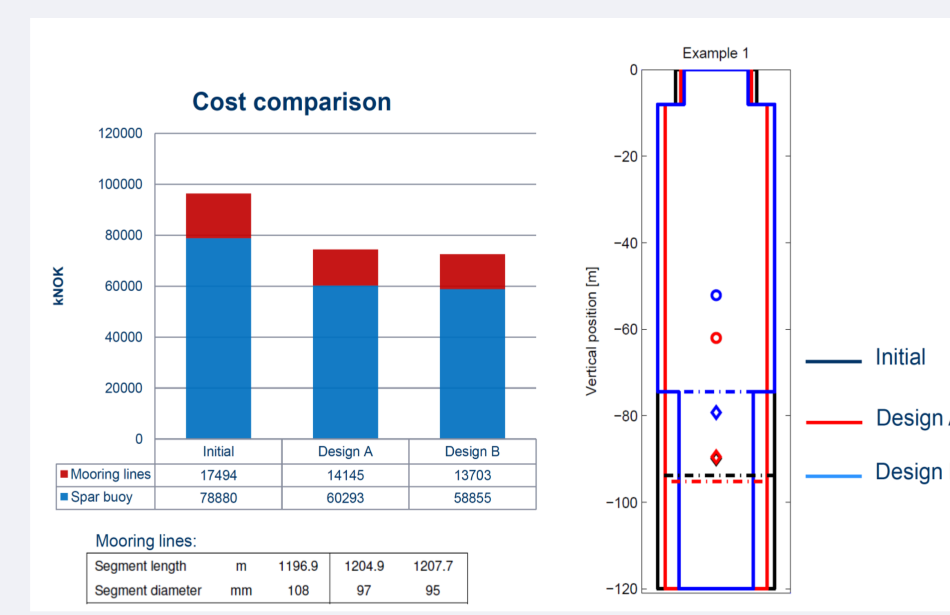
Simulations show transverse forces on the rotating spar buoy due to strong currents posses an important load contribution. The combined interaction of wind, wave and current show a stable precession pattern with maximum 14 deg tilt.

Load case 1: wind :14 m/s wave: 4 m height, 0.9s period. max tilt ≈3° Load case 2: wind :14 m/s, 1m/s currents max tilt ≈14°

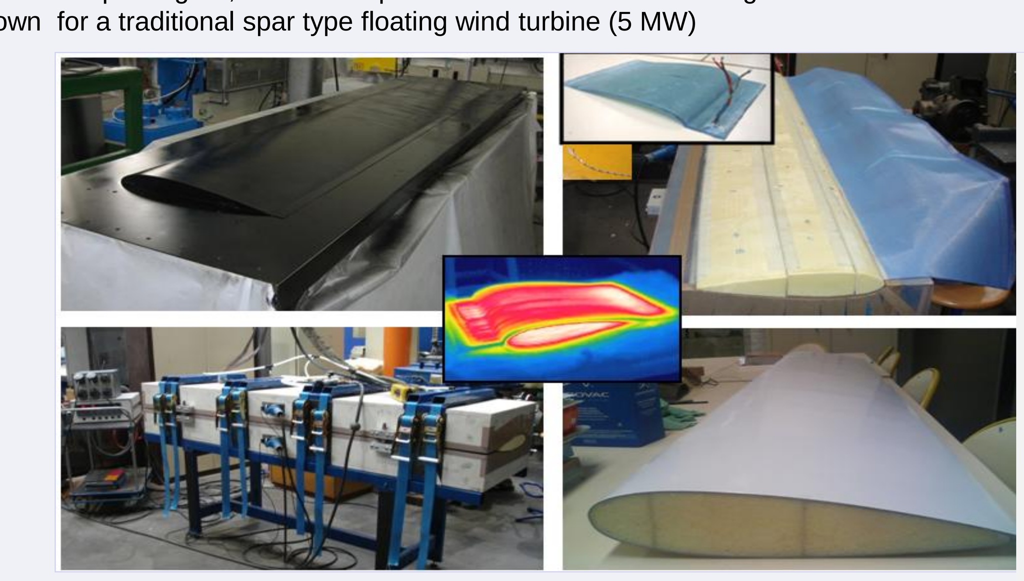




In work package 6 the fluid interaction on a rotating cylinder in water has been studied further for the measurements of drag and lift forces. and torque. A CFD simulation carried out with effects as shown due to current, waves, and rotation of the cylinder at high Re-number.

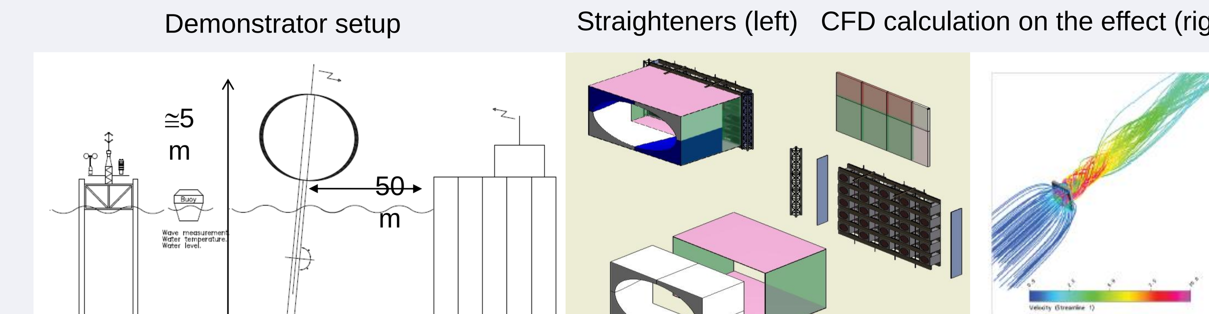


From work package 5, a cost comparison for three different designs from WINDOPT results is shown for a traditional spar type floating wind turbine (5 MW)



NENUPHAR has developed an innovative blade manufacturing process that optimizes mechanical (dynamic) behavior with a low weight and high stiffness structure. A blade of 7.8 meters has been successfully manufactured. This manufacturing process is used in DeepWind for exploration of pultrusion technology and can be easily scaled-up for large-size blades..
In work package 7 the design of the 1 kW sized turbine has started along with the specific siting of the turbine in Roskilde fjord at Risø campus. The plan for first test in the fjord is scheduled for this summer, and campaigns for the operational unit starting August-September. The instrumentation design phase is ongoing with proper selection of the sensors ,and a NI CRIO DAQ system(400hz) has been acquired. For the tank tests, MARIN has conducted studies how to implement suitable wind conditions in the laboratory facility. To assist in the DeepWind model testing, MARIN is developing at the moment a high quality local wind field modelling set-up. This consist of a square bed of 5*5 wind fans (4m*3m) with guides and stators (straighteners), close to the turbine. By controlling the RPMs of the different rows, the vertical profile of the wind can be controlled. The present set-up which is under construction is given in the Figure .

Demonstrator setup Straighteners (left) CFD calculation on the effect (right)



Conclusions

- •Aero-elastic simulation tool performs as planned (WP1)
- •A feasible blade manufacturing process (WP2)
- •A feasible cost optimisation tool ready (WP5)
- •Test layout for fluid interaction tests ready (WP6)
- •First iteration in1kW demonstrator design started (WP7)
- •Design of wind array system for tank tests started (WP7)

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